RESULTS OF OBSERVATIONS OF THE ECLIPSE BY THE EXPEDITION FROM THE YERKES OBSERVATORY.

By EDWIN B. FROST.

(*Read April 25, 1919.*)

The expedition from the Yerkes Observatory for the observation of the solar eclipse of June 8, 1918, occupied three stations: the principal one at Green River, Wyoming, the second at the Chamberlin Observatory at the University of Denver, and (3) a site near Matheson, Colorado, which had been selected by Professor Barnard and the writer on a reconnaissance trip in 1917.

At the last-named station, Professor Edison Pettit, of Washburn College, Topeka, Kansas, who was at the time an assistant at the Yerkes Observatory, aided by Miss Hannah B. Steele, then fellow in astronomy at the University of Chicago, and by others, obtained some good photographs of the corona with the use of the twelve-inch objective of Washburn College, stopped down to an aperture of four inches, combined with a moving plate according to Schaeberle's method. The first slide shows one of Mr. Pettit's best pictures, with an exposure of one second. The weather was unfavorable in the weeks preceding the eclipse for a considerable extent of the track of totality, but it fortunately cleared at Matheson at the time of the eclipse. Other parties which made successful observations at this station were that of Professor Loud and Mr. Hartley, that from Drake University under Professor Morehouse, and that from the University of Toronto under Professor Chant.

At Denver we received the great courtesy from Director Howe of the use of the twenty-inch Clark equatorial. A special auto-collimating spectroscope with a Michelson plane grating belonging to the Yerkes Observatory was adapted in our shops to fit the Denver equatorial. Professor Schlesinger kindly loaned us an attachment from the Porter spectrograph of the Allegheny Observatory whereby we could bring into juxtaposition images from the east and west limbs of the sun. The scale was about 22 A per mm., and the definition good. The intention was to photograph the green coronal line out to about two minutes of arc from the eastern and western limbs of the sun in order to determine, if possible, the rotation of the corona. With clear weather, we should have had as good a chance of making this test as has been had thus far by other expeditions. The writer spent ten days at Denver getting everything ready, at the end of May, and the observations were to be made by Professor R. S. Nyswander. Unfortunately the day was completely cloudy in the vicinity of Denver.

On the observatory grounds at Denver, we had also installed a small cœlostat for the direct photography of the corona, utilizing a five-inch objective of twenty-two feet focus, belonging to the Denver equatorial. The installation of this apparatus was attended to by Professor Paul Biefeld, of Denison University, who kindly volunteered his services.

The main station at Green River had also been selected in the previous year, when it was visited by Professor Barnard and the writer on a day of extraordinary atmospheric clearness. The weather records for many years seemed to promise extremely well for this station, although there was much bad weather during the six weeks after our camp was established. The elevation of the station was about 6,200 feet. The day of the eclipse was fine until after noon, when white cumulus clouds began to drift across the sky. A large triangular cloud covered the sun at the time of first contact and moved away with aggravating slowness, so that there was a fair question for twenty minutes previous to totality whether or not the sun would be covered by the cloud. Unfortunately the cloud did not drift away until some three minutes after totality.

Although we had a fine view of the corona and of the brilliant prominences through the edge of the cloud, the spectroscopic observations were very greatly impaired. To me, the visual phenomena of the eclipse were much more impressive than they were in a perfectly clear sky at Wadesboro in 1900.

The direct photographs of the corona and prominences were made under Professor Barnard's direction: (1) with the cœlostat and a six-inch objective of sixty-two-feet focus, with the exposures by Miss Mary R. Calvert, who had her station in the dark room; (2) with the twelve-inch Kenwood equatorial of this observatory, operated by Professor Barnard, with several smaller cameras attached to the tube. Professor Barnard makes the following comment on the apparent connection of some of the coronal streamers with prominences:

"APPARENT CONNECTION OF SOME OF THE CORONAL STREAMERS WITH PROMINENCES.

"Perhaps no photographs of a previous eclipse have shown with such beauty and distinctness the succession of expanding arches that must have extended above some of the prominences like great spreading envelopes. This is strikingly shown by a large coronal form, made up of numerous arches that seem to center about the remarkable "skeleton" prominence, the position angle of whose base is 253°. A similar but smaller form and arches are centered about a small prominence in position angle 206°. There are other cases, but the arches are not so well developed.

"The intimate connection of some of the coronal streamers with some of the prominences is best shown by a small prominence in position angle 234°, from which a coronal streamer apparently emanates and in which it seems to have its actual origin. Close to this, to the west, is a long, low-lying prominence, in position angle 240°, in which similar coronal streams seem to have their origin. Originating apparently in a projection in the southerly part of this prominence, a broad stream bends westward over the entire prominence. From the great prominence in position angle 298° there are strips of matter apparently streaming southward toward the equator, as if impelled by some directing force.

"On account of the large scale on which they are taken, these features are shown to good advantage on the photographs with the 61½-foot cœlostat."

It had been my hope that we could apply to the problem of the rotation of the corona the method of the interferometer so successfully used by Messrs. Fabry, Buisson and Bourget in photographing interference fringes in the Orion nebula (*Astrophysical Journal,* Vol. 40, pp. 241–258, 1914). While this method would be quite difficult of application and there might be a reasonable doubt as to whether sufficient exposure could be given to secure a proper impression of the rings from the green coronal line, nevertheless a successful photograph would be of the greatest value, both for studying internal motions of the corona and its rotation as a whole.

I had the great advantage of discussing this with M. Fabry during his visit to the United States as chairman of the French Scientific Mission. He very kindly offered the loan of the apparatus used at Marseilles, and, if it had arrived in time, we should have tried the method, employing a rather small image of the sun in the hope of getting sufficient intensity. Unfortunately the apparatus did not reach us until long after the eclipse.

I hope that this method will be properly tested at some future eclipse.

The flash spectrum as hitherto photographed has represented a composite of the successive images of the different reversing lines during the critical second or two at second and third contacts. Exceptions to this have been the instances where Professor Campbell has employed a falling plate. I am not sufficiently familiar with the results thus obtained, of which I have not seen reproductions, to know how definitely the different stages of the brief phenomenon are recorded. It seemed to me that the movie camera was at present in a sufficient state of development to be successfully applied to this problem. A "Universal" type of camera was employed, with its short-focus lens removed, and this was attached, without alteration or injury to the machine, to an objective-prism spectroscope having three large Mantois prisms and a special camera lens of 5 cm. aperture and 40 cm. focus. This gave a scale of 13 A per mm. in the vicinity of $H\gamma$. Only a small portion of the spectrum can be photographed with the commercial machine because of the size of the film, which allows an image 1 inch $\times$ ¾ inch (25 mm. $\times$ 18 mm.). A region would naturally be selected in which important lines occurred, or such as it was desired to study particularly. The correct exposure was naturally a question of some uncertainty in advance of the event. This is, of course, determined by the rate at which the crank of the machine is turned. It is arranged for eight pictures per turn, and after some preliminary experiments, I decided that it was safe to have the crank operated at the rate of two turns per second, giving sixteen pictures per second. Inasmuch as about half of the time was used in moving the film between exposures, this would represent about $1/30$ of a second for the exposure. On account of the clouds still lingering over the sun, it was not possible to obtain satisfactory pictures at the beginning and end of totality for bringing out the delicate details of the flash. But it is perfectly evident from the pictures that an excellent record of the successive stages of the development of the flash would have been obtained if the sky had been clear. This slide shows a few of the pictures taken several seconds after totality: it will be possible to notice the tips of bright gamma still reversed. The next slide shows a few of the exposures, successively of the 15th, 18th and 23d seconds after totality. Over 2,000 impressions of the spectrum were obtained.

Another and important advantage of this method is that it removes all the uncertainty of making the exposure at the correct instant to secure the flash. This has been a matter of difficulty and consequent nervousness on the part of the observers, even if the signal should be given by a person observing the flash itself visually. By beginning to operate the machine half a minute before the expected time of totality, and running it for a few seconds after totality has begun, there could be no doubt about catching the phenomenon at all the stages and hence precisely at the best instant. Thus the history of the reversal of each line should be shown, and it would be very different for those of high level and those of low level. This could be demonstrated to an audience or to a class by the use of the film itself, and the film of course could be measured as well as an ordinary photographic plate.

It is very easy to connect a chronometer with the machine so as to impress a dot on the film every second or half second, so that the precise instant of each exposure can be known. At Green River, Mr. Blakslee of our staff operated the crank and he was to receive the signal from me as I watched the spectrum with a spectroscope for this purpose. However, I decided during the partial phase that it would be safer to begin the exposure one minute before the predicted time of totality. As a matter of fact, owing to the cloud, I was unable to see the flash spectrum at the beginning of totality and could see the reversal of but few lines at the end of totality.

It would also be perfectly feasible to operate the film by a direct connection with a chronograph, controlled by a conical pendulum; or, if desired, a graduated change in rate of rotation could be given so that a longer exposure would result before totality (say, an exposure of $\frac{1}{20}$ second) and a still shorter (say, $\frac{1}{50}$ second), thirty seconds before and after the contacts. I sincerely hope that this simple method will be included in the plans for the next eclipse expedition, because with clear weather it practically guarantees good results.

I may say here that it is unfortunate that better records of the eclipse were not obtained with movie machines. So far as I have learned no first-class picture was obtained. I took pains to notify some of the film companies, explaining how important it was that they should not depend upon their usual short-focus lenses (two to three inches), but that they should use lenses of at least twenty or thirty inches focus. Some commercial operators at Denver were prepared to do this, and doubtless would have obtained results both instructive and interesting if the weather had permitted.

Our program also included the photography of the infra-red region of the spectrum, with the use of films stained with dicyanin, in connection with a small concave grating of sixty inches focus, used directly. This was the instrument I had employed at Wadesboro in 1900. It was operated by Professor S. B. Barrett, but no results in the infra-red could be obtained through the cloud. It might be a question whether there would be ordinarily time enough for sufficient exposure for the infra-red, and probably future plans in this direction should insure an abundant light-power in the spectroscope.

In connection with the apparatus arranged by Professor Parkhurst for the photometric study of the corona was a reflecting telescope of six inches aperture and sixty inches focus, covered by a 15° prism of ultra-violet glass of the same aperture. One of the exposures made with this instrument is shown herewith, as it brings out an interesting point with respect to the large prominence in position angle 253°, already shown from Professor Barnard's negative and designated by some as the "heliosaurus." As may be seen from the slide, the prominence is visible only in the H and K lines of calcium. If present at all in the other emissions it is too weak to impress the plate. On the contrary, the quiet prominence at position angle 297° (= north latitude 40°) appears also in the $H\beta$, $H\gamma$, and $H\delta$ lines, and the prominence at position angle 51° (= north latitude 26°) is bright in helium D_3 as well as in the hydrogen series.

The low prominence or uncovered photosphere at position angle 240° (= south latitude 17°) shows a remarkable extension into the ultra-violet, the bright group between wave-lengths 3350 and 3390 A being especially strong. This prominence is an origin of coronal streamers, as Professor Barnard has shown in his paper on page 223.

The continuous spectrum of the corona is so strong that it masks the narrow rings due to the bright coronal lines at wave-lengths 5303, 4231 and others.

YERKES OBSERVATORY,
April 18, 1919.